Journal for Worldwide Holistic Sustainable Development

ONLINE ISSN: 2409 9384

PRINT ISSN: 2414 3286

2020 VOLUME 6 ISSUE 2

Comparative Study on Carbon Sequestration Potentials of *Gmelina arborea* Roxb. and *Tectona grandis* L.f Seedlings

Authors: Asinwa, I. O., Kazeem Ibrahim, F., Agbeja, A. O., Iroko, A. O., Bobadoye, A. O. and Aina-Oduntan, O. A

Forestry Research Institute of Nigeria, P.M.B, 5054, Ibadan, Nigeria

Corresponding Author: israelasinwa@gmail.com/ Tel: 08035519395

Abstract

Deforestation and forest degradation are the main sources of greenhouse gas (GHG) emissions in most tropical regions which result in climate change. Tree crops play a significant role in mitigation of this dangerous phenomenon through CO_2 sequestration. The study therefore investigated carbon sequestration potentials of seedlings of *Gmelina arborea* and *Tectona grandis*.

Seeds of *G. arborea* and *T. grandis* were sown differently in germination boxes. Eighty seedlings of each tree species were selected and 5 seedlings from each species were harvested carefully and excised into roots, stem and leaves fortnightly for 10 weeks to determine sequestered carbon contents. The experimental design was Completely Randomized Design (CRD) with 2 and 5 replicates. Data was subjected to analysis of variance (ANOVA) and correlation analysis to determine the relationship between carbon content in leaves, stems and roots.

There was no significant difference in the carbon content of the roots of the two species ($P > 0.05$) while carbon contents in leaves, and stems were significantly different ($P < 0.05$). The fortnightly carbon sequestration by *G. arborea* and *T. grandis* increased with increase in number of weeks (age). The foliage carbon content of *G. arborea in the first* two weeks of study was higher (0.22g) than that of *T.grandis* (0.15g). This trend continued till 10th week with *G. arborea* (2.67g) and *T. grandis* (1.19g). At the end of the study period, stems of *G. arborea* had a higher carbon content (1.36g) while the stems of *T. grandis* had 0.45g. Roots of the seedlings of the two species had the least carbon contents at the end of the study (*G. arborea*: 0.93g and *T. grandis*: 0.66g) when compared to leaves and stem. The final carbon content of *G. arborea* seedling at the end of 10th week was 4.96g higher than *T. grandis* with 2.3g.

The assimilation rate of the seedlings bolstered the biomass of the two species of which carbon content is the main component.

Keywords: Forest degradation, Climate change, Biomass, Carbon dioxide, Sequestration

Introduction

Carbon dioxide (CO_2) is a major greenhouse gas among the principal gases causing global warming. The gas is released in excessive amounts via anthropogenic activities such as and including indiscriminate forest removal. CO_2 is trapped in the atmosphere, thereby raising the global temperatures (FAO, 1997). This poses a harmful challenge to humans as it increases the incidence of carcinogenic diseases, flooding as a result of ocean rise and melting of the polar ice in Polar Regions, aggravates drouts in the continental hinterland and loss of bio-resources of food and medicine (Label and Kane, 1989; Odjugo, 2009).

As consequent of various human activities such as deforestation and fossil fuel combustion Atmospheric CO_2 continues to increase. This has resulted into a phenomenon known as climate change, which is a contemporary harmful to the existence of man, livestock and environment generally. This is characterized by a consistent unfavorable climate exemplified in the rising earth temperature which is referred to as global warming. Deforestation and forest degradation account for between 15% - 20% of global carbon emissions, and most of that comes from tropical regions of the world (Odjugo, 2009). Approximately 60% of the carbon sequestered by forests is released into the atmosphere through deforestation (Gullison *et al.,* 2007). Deforestation of tropical forest releases about 1.5 Gt of carbon into the atmosphere every year (Gullison *et al.,* 2007). According to Gullison *et al.* (2007), deforestation and forest degradation are the main sources of greenhouse gas (GHG) emissions in most tropical regions and has a greater influence on the ecosystem generally.
Because the forests are estimated to store about 650 billion tons of carbon and absorb 8.5 billion tons of CO2 per year from the atmosphere (Nabuurs, 1998), forest ecosystems of the tropics therefore have a major role to play in the mitigation of this dangerous phenomenon. Forests store carbon and comprise about 80% of the entire above-ground organic carbon and 40% of the total below-ground organic carbon worldwide (FAO, 2011). They also contain one of the major carbon pools and have a substantial function in the global carbon cycle (FAO, 2011).

Trees use the carbon absorbed by leaves during photosynthesis to maintain cellular structures and grow new tissues. Maintenance of existing tissues requires an expenditure of carbon during respiration, which then reduces the carbon available for new growth (Bombelli et al., 2009). The net carbon available to a tree, along with required nutrients, is then allocated to the growth of leaves, roots stems, flowers and seeds (Bazzaz, 1996). All the same, tree seedlings utilize carbon from carbon dioxide in the process of photosynthesis towards attaining maturity. Sequestration of CO_2 occurs at every developmental stage of the forest and different plants store CO_2 at different rates and levels (Basuki *et al*., 2009). In order to ascertain how trees sequester CO_2, several studies have been carried out with different, destructive methods to directly measure the biomass by harvesting the tree and measuring the actual mass of each of its compartments, (e.g., roots, stem, branches and foliage) (Kangas and Maltamo, 2006). Indirect methods also attempt to estimate tree biomass by measuring variables that are more accessible and less time-consuming to assess (for instance, wood volume and gravity) (Peltier *et al*., 2007). More so, allometric equations have also been used for several forest estates with little or no effort on nursery-grown tree seedlings (Kettering *et al*., 2001). This study therefore investigated carbon sequestration potentials of seedlings of *Gmelina arborea* and *Tectona grandis*, endemic fast-growing tree species, with a view to determining the level with which they sequester CO_2.

Materials and Methods
The study was carried out at the Silviculture Nursery of the Department of Sustainable Forest Management (SFM), Forestry Research Institute of Nigeria (FRIN), Jericho Hill, and Ibadan,

Journal for Worldwide Holistic Sustainable Development

ONLINE ISSN: 2409 9384

PRINT ISSN: 2414 3286

2020 VOLUME 6 ISSUE 2

Nigeria. FRIN is located on the longitude $07^0$23'18"N to $07^0$23'43"N and latitude $03^0$51'20"E to $03^0$51'43"E.

Seeds of *Tectona grandis* and *Gmelina arborea*, which are fast growing tree species, were procured and sown differently in germination boxes. The germinated seedlings were pricked into polythene pots filled with topsoil. Pre-planting soil analysis of the topsoil was carried out in order to determine the initial carbon content and post-harvesting analysis was done after each harvest of tree seedlings.

Eighty seedlings of each tree species were selected and at the end of the 2^{nd} week, 5 seedlings from each species were harvested carefully and excised into roots, stem and leaves. Fresh weight of each seedlings part was determined, using a sensitive weighing balance, after which they were oven-dried at 70^0C until they attain constant weight in order to estimate their biomass. The carbon content was determined by conversion of biomass to C through use of the coefficient (0.55). That is Carbon stock: C = 0.55 x Total biomass (MacDicken, 1997). The organic carbon in the soil after each harvest of the seedlings was determined through soil analysis to know exact carbon sequestered by the seedlings.

This was done fortnightly for 10 weeks. The ratio of carbon content in root, stem and leaves at each period of harvesting was determined.
The experimental design was Completely Randomized Design (CRD) with 2 species as treatments replicated 5 times. Data was subjected to analysis of variance (ANOVA) and correlation analysis was used to determine the relationship between carbon content in leaves, stems and roots of *Gmelina arborea* and *Tectona grandis* seedlings.

Results

The physico-chemical properties of the soil before and after study are presented in table 1. The organic carbon of the soil where *G. arborea* and *T. grandis* seedlings were planted relatively decreased after harvesting (*G. arborea:* 15.1cmol/kg and *T. grandis*: 15.8 cmol/kg). Other physico-chemical properties of the soil followed similar trend.
Table 2 shows Analysis of Variance among carbon contents sequestered by leaves, stems and roots of *G. arborea* and *T. grandis* seedling within 10 weeks of study. There was no significant difference in the carbon content of the roots of the two species ($P > 0.05$) while carbon contents in leaves, and stems were significantly different ($P < 0.05$). The total carbon contents in *G. arborea* and *T. grandis* seedlings within period of study were also significantly different.

Table: 1. Physico-Chemical Properties of Topsoil used for Raising Seedlings of *Gmelina arborea* and *Tectona grandis*

Nutrients	Pre- planting Quantity	Post-planting Quantity (Ga)	Post- planting Quantity (Tg)
O.C (cmol/kg)	17.8	15.1	15.8
O.M (cmol/kg)	30.6	21.3	23.7

Journal for Worldwide Holistic Sustainable Development
ONLINE ISSN: 2409 9384
PRINT ISSN: 2414 3286
2020 VOLUME 6 ISSUE 2

T.N (cmol/kg)	1.5	0.9	1.1
K (cmol/kg)	0.11	0.06	0.07
Na (cmol/kg)	1.27	0.98	1.2
Ca (cmol/kg)	5.19	3.07	3.43
Mg (cmol/kg)	2.34	1.89	2.0
Mn (mg/kg)	26.1	24.1	24.8
Cu (mg/kg)	0.8	0.7	0.6
Zn (mg/kg)	3.1	2.8	2.7
Fe (mg/kg)	36	29	31
P (mg/kg)	51.92	43.23	45.01
Sand%	86.5	86.5	86.5
Clay%	9	9	9
Silt%	4.5	4.5	4.5
pH (H_2O)	6.69	6.67	6.68

Table 2: Analysis of Variance (ANOVA) for Carbon Contents of leaves, stems and roots of *Gmelina arborea* and *Tectona grandis* seedling within 10 weeks of study

Parameters	SV	df	SS	MS	F-cal	P-Value
	Species	1	.222	.222	5.935	.041*
Leaves	Errors	8	.299	.037		
	Total	9	.521			
	Species	1	.083	.083	49.145	.000*
Stems	Errors	8	.013	.002		
	Total	9	.096			
	Species	1	.007	.007	2.581	.147ns
Roots	Errors	8	.023	.003		
	Total	9	.030			
	Species	1	.713	.713	11.858	.009*
Total	Errors	8	.481	.060		
Carbon	Total	9	1.194			

*****=significant at $P<0.05$
ns =not significant at $P>0.05$

The correlation analysis of carbon content in the roots of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings depict a positive and strong relationship (0.94g). This is followed by relationship between leaves (0.69g), stem (0.51) and the least correlation value was determined for the total carbon contents in Ga and Tg (Table 3)

Table 3: Relationship between Carbon content of leaves, stems and roots of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings

Variable	Species	Average C	St.dev	r-value
Leaves	Ga	0.2422	0.2149	
	Tg	0.1208	0.09211	0.69*
Stem	Ga	0.1322	0.160631	
	Tg	0.0378	0.04523	0.51*
Root	Ga	0.0834	0.074788	
	Tg	0.045	0.055	0.94*
Total	Ga	0.4324	0.368	
	Tg	0.197	0.1702	0.8*

* P<0.05

The fortnightly carbon sequestration by Ga and Tg are shown in figures 1- 4. Generally, carbon contents increased with an increase in the number of weeks (age). The foliage carbon content of Ga at first two weeks of study was higher (0.22g) than that of Tg (0.15g). This trend continued till 10th week with Ga (2.67g) and Tg (1.19g) (Fig. 1)

At the end of the study period, stem of Ga had higher carbon content (1.36g) while Tg had 0.45g (Fig. 2). Roots of the seedlings of the two species had the least carbon contents at the end of the study (Ga: 0.93g and Tg: 0.66g), when compared to leaves and stem (Fig 3). The total carbon content in the two species is presented in figure 4. The carbon content of Ga at the end of 10th week was 4.96g, which is higher than Tg with 2.3g of carbon. The trend began from the second week of data collection.

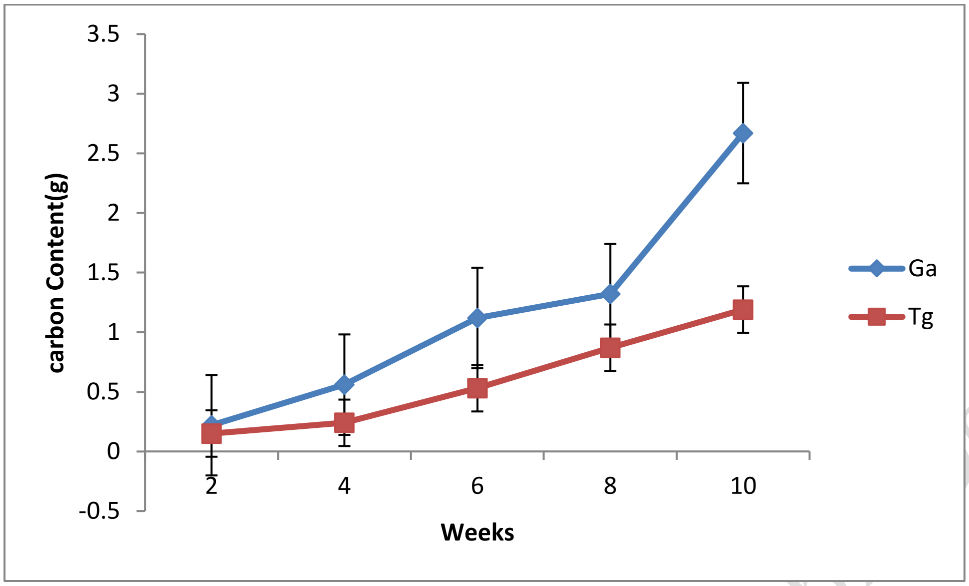

Figure 1: The estimated carbon sequestered by leaves of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings within 10 weeks of study.

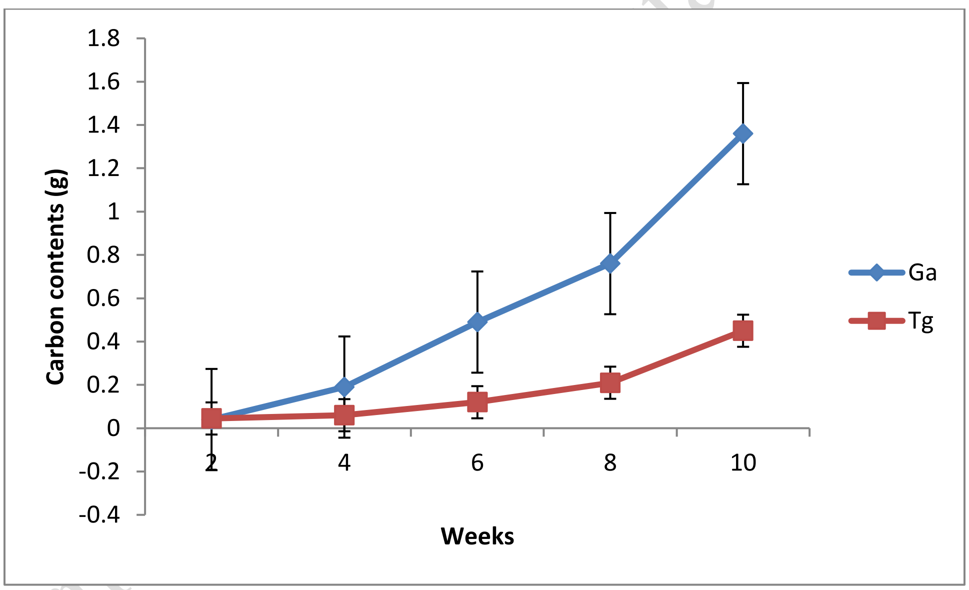

Figure 2: The estimated carbon sequestered by stem of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings within 10 weeks of study.

Journal for Worldwide Holistic Sustainable Development
Online ISSN: 2409 9384
Print ISSN: 2414 3286
2020 Volume 6 Issue 2

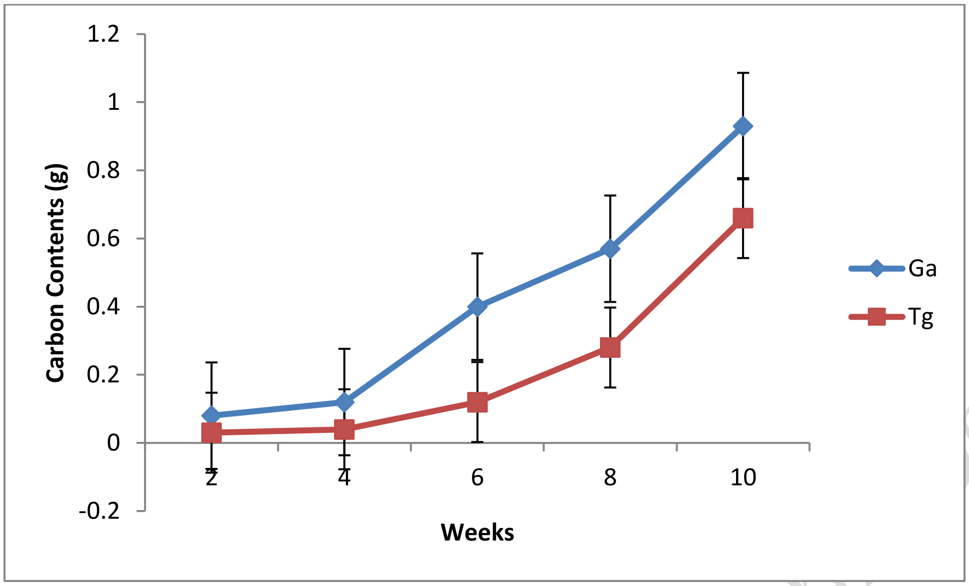

Figure 3: The estimated carbon sequestered by roots of *Gmelina arborea* (Ga) and *Tectona grandis* (Tg) seedlings within 10 weeks of study.

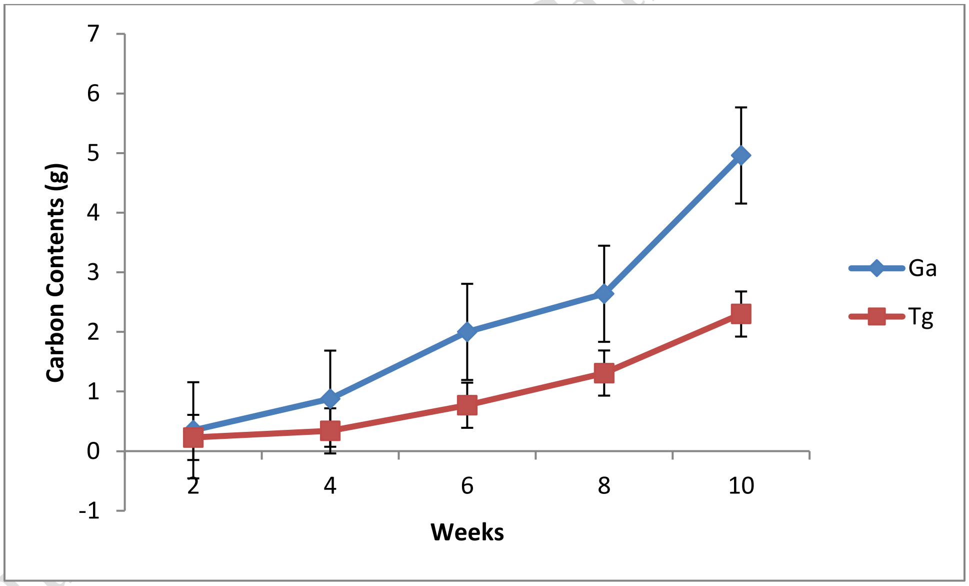

Figure 4: The estimated total carbon sequestered by *Gmelina arborea* (Ga) and *Tectona grandis*(Tg)seedlings within 10 weeks of study.

Discussion

Growth and development of every part of the plant is subject to new tissue production, aided by meristems located at the tips of organs or between mature tissues. This phenomenon is the function of one or more factors, out of which carbon from CO2 plays a significant role, most especially during photosynthesis (Bäurle and Laux, 2003; Brand, et al., 2001). According to (Barlow, 2005), the role of carbon, whether from the air or organic carbon in soil, on plant growth is extremely valuable and, as a matter of fact, without this process, life as we know would not exist.

Different plant species exhibit natural variation in their forms, structures and growth rate, while some even exhibit an additional type of variation within a single individual. Variations do occur in different plant parts (Bäurle and Laux, 2003). Consequently, significant variation in carbon contents of leaves and stems of the Gmelina arborea and Tectona grandis seedlings depict differences in growth rate and development of the two species. The differences could be attributed to physiological processes and environmental effects. According to Conroy (1999), there is variation in metabolism and carbon sequestration among different parts of a plant and different species based on the relative position of the organ production. Leaves are the most important plant component, having a role in production. They play a major role in the flow of energy, matter and converting them between the land and atmosphere. Every year, trees produce new leaves to perform photosynthesis and thus, carbon sequestration transfers from the atmosphere increasing their biomass (Brandão and Levasseur, 2011). In fact, annual leaf production alone generates a large amount of biomass (Bird et al., 2011)

For instance, it was observed that along a new branch, the leaves may vary in a consistent pattern along the branch. The form of leaves produced near the base of the branch differs from leaves produced at the tip, and this difference is consistent from branch to branch on a given plant and in a given species. The variation consequently influences different sequestration ability of different plant parts (Eamus *et al.*, 1995).

Carbon assimilation and direct effects of CO_2 on tree seedling growth and biomass accumulation are compounded by soil nutrient input and foliar nutrition, which varies from species to species (Conroy, 1992). According to Wong *et al*., (1992); Conroy *et al.* (1990a) and Conroy *et al.,* (1990b) the carbon sequestration and nutrient intake by *Eucalyptus grandis* and *Eucalyptus. camaldulensis* differs, and also *Pinus ocarpa, Pinus radiata* and *Eucalyptus caribaea* varied in the study carried out on the species.

Carbon sequestration, which is enhanced by positive nutrient intake on young trees, can be attributed to compounding effects of increased leaf production and leaf area of the plants (Conroy *et al.,*1992). This also depends upon interception and utilization of sunlight, but subsequent use necessitates expenditure of metabolic energy (*Bäurle and Laux, 2003)*. The carbon content in the plant dry matter is subject to metabolic activities associated with growth and maintenance of plants and can be represented by biomass equivalents *(*Bäurle and Laux, 2003). The increase in carbon content with age in *Gmelina arborea* and *Tectona grandis* seedlings depicts that the biological energy derived from respiration sustains maintenance and growth as well as life support through supply of oxygen and environmental sustainability (Conroy *et al.*, 1992). Green plant respiration corresponds to suction of CO_2 associated with production of energy for maintenance of chemical and electrochemical gradients across membranes, turnover of cellular constituents suc h as proteins and physiological acclimation to harsh environments (Nabuurs, 1998). Growth covers synthesis of new biomass, which chiefly constitutes carbon from photo assimilate and nutrients. Despite the increase in the carbon contents of the two species, the higher carbon in *G. arborea* seedlings in all growth parameters could be attributed to growth and assimilation rate in addition to the chemical composition of plant material, and by implication, the amount of energy capable to be produced by the species (Bombelli *et al*., 2009). Basuki *et al*. (2009) opined that the way in which new plant structures mature may be affected by the point in the plants life when they begin to develop or accumulate biological materials, as well as the environment to which the structures are exposed.

The higher carbon contents sequestered by the leaves of the two species throughout the period of the study corroborate the findings of (Basuki*et al*., 2009) that leaves produced during early growth tend to be larger with higher assimilation rate.

Conclusion

Seedlings of the two species; *Gmelina arborea* and *Tectona grandis* sequesters CO_2 from the atmosphere to accumulate biomass. As the seedlings of the species develop with time, the bio sequestration increases, and biomass accumulation is enhanced. The assimilation rate of the seedlings bolstered the biomass of the two species of which carbon contents is the main component. Though the carbon contents estimated from *Gmelina arborea* was higher than that of *Tectona grandis,* their sequestration potentials were correlated to one another. It can therefore be established that assorted seedlings in the nursery contribute immensely to the climate change amelioration through carbon sequestration.

REFERENCES

Barlow, P (2005). "Patterned cell determination in a plant tissue: The secondary phloem of trees". BioEssays. 27 (5): 533–41. Accessed on 10/01/2020

Basuki, T.M., Van-Laake, P.E., Skidmore, A.K. and Hussin, Y.A. (2009): “Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests”, *Forest Ecology and Management* 257 (8): 1684-1694.

Bäurle, I and Laux, T (2003). "Apical meristems: The plant's fountain of youth". BioEssays. 25 (10): 961–70. Accessed on 10/01/2020

Bazzaz, F. A. (1996). Plants in changing environments: linking physiological, population, and community ecology. Cambridge University Press, Cambridge, pp 332.

Bird, D. N, Cowie, A, Strømman, A. H and Frieden, D (2011): The timing of greenhouse gas emissions from bioenergy systems using financial type indicators and terminology to discuss emission profiles from bioenergy. In Proceedings of the 19th European Biomass Conference and Exhibition, Berlin. 10.5071/19thEUBCE2011-VP5.2.6

Bombelli, A., Avitabile, V., Belelli-Marchesini, L., Balzter, H., Bernoux, M., Hall, R., Henry, M., Law, B.E., Manlay, R., Marklund, L.G. and Shimabukuro, Y.E. (2009): Assessment of the status of the development of the standards for the Terrestrial Essential Climate Variables: Biomass. Food and Agriculture Organization – Global Terrestrial Observation System. 18 p.

Brand, U., Hobe, M and Simon, R (2001): "Functional domains in plant shoot meristems". BioEssays. 23 (2): 134–41. Accessed on 10/01/2020

Brandão, M and Levasseur A (2011): Assessing temporary carbon storage in life cycle assessment and carbon footprinting: Outcomes of an expert workshop. Publications Office of the European Union, Luxembourg. ISBN 978-92-79-20350-3.

Conroy, J. P. (1999): Factor interaction and CO2 enrichment. In: BJ. Atwell, P.E. Kriedemann andC.G.N. Turnbull (eds). *Plants in Action.* Ch.13.3, pp. 422-428. ASPPlMacMillan, SouthYarra.

Conroy, J.P., Milham PJ. and Barlow, E.W.R. (1992). Effect of nitrogen and phosphorus availability on the growth response of *Eucalyptus grandis* to high CO_2, *Plant, Cell* and *Environment.* 15: 843-847.

Conroy, J.P., Milham P.J., Mazur, M. and Barlow, E.W.R. (1990a). Growth, dry weight partitioning and wood properties of *Pinus radiata* D. Don after two years of CO2 enrichment. *Plant, Cell* and *Environment* 13: 329-337.

Conroy, J.P., Milham PJ., Reed, M.L. and Barlow, E.W. (1990b). Increases in phosphorus requirements for CO_2-enriched pine species. *Plant Physiology* 92: 977-982.

Eamus, D., Berryman, C.A. and Duff, G. (1995): The impact of CO_2 enrichment on water relations of *Maranthes corymbosa* and *Eucalyptus tetrodonta. Australia Journal of Botany.* 43: 273-282.

Food and Agriculture Organization (1997): Forest harvesting in natural forests of the Republic of Congo, Forest Harvesting Case Studies-07, Food and Agriculture Organization of United Nations (FAO), Rome, Italy.

Food and Agriculture Organization (2011): *State of World’s Forest*; Food FAO: Rome, Italy.

Gullison, R.E.; Frumhoff, P.C.; Canadell, J.G.; Field, C.B.; Nepstad, D.C.; Hayhoe, K.; Avissar, R.; Curran, L.M.; Friedlingstein, P.; Jones, C.D. (2007): Tropical forests and climate policy. *Science*, *316*, 985–986.

http://lct.jrc.ec.europa.eu/assessment/publications

Intergovernmental Panel on Climate Change (2006): *IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme*. Tokyo: Inst. Glob. Environ. Strateg.

Kangas, A. and Maltamo, M. (2006): Forest inventory, Methodology and Applications. *Managing Forest Ecosystems* 10: 179-194

Ketterings, Q. M., Coe, R., Noodrdwijk, M., Ambagau, Y. and Palm, C.A. (2001): Reducing uncertain ty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. *Forest Ecology and Management* 146:199–209.

Label, G. G. and Kane, H. (1989): Sustainable Development: A guide to our common future. The Report of the World Commission on Environment and Development. Global Tomorrow Coalition, Washington, U.S.A.

MacDicken, K.G (1997): A guide to monitoring carbon storage in forestry and agroforestry projects. Winrock International Institute for Agricultural Development, Arlington, VA (USA). Forest Carbon Monitoring Program eng

Nabuurs, G. J. (1998): Kyoto Forests. Change. Research and Policy Newsletter on Global Change from the Netherlands, 43, RIVM/NRP, Bilthoven.

Odjugo, P. A. O. (2009): Quantifying the cost of climate change impact in Nigeria: Emphasis on wind and rainstorm. *Journal of Human Ecology* 28(28): 93-101.

Peltier, R., Njiti, C. F., Ntoupka, M., Manlay, R., Henry, M., and Morillon, V., (2007): Evaluation du stock de carbone et de la productivité en bois d'un parc à Karités du Nord-Cameroun. *Bois et forêt des tropiques* 294: 39–50.